Exploring "Tree Rings" in Simulated LSST Sensors

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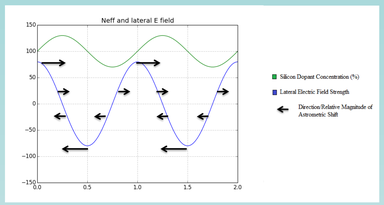
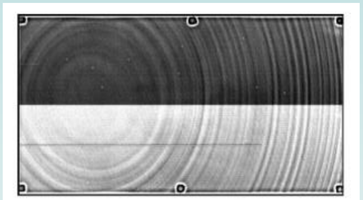
"Tree Rings"

- Periodic variations in dopant concentration as a function of distance from the center of the silicon boule are typical.
- Dopant concentration gradient results in parasitic lateral electric fields directed along the radius of the original silicon boule.
- Lateral electric fields cause the electrons to deviate from the path the photon was following prior to conversion, leading to systematic errors in measured position and shape which will impact the quality of LSST's science results if uncorrected.





Tree Rings in DECam sensors.
Source:
http://arxiv.org/pdf/1403.6127v3.pdf

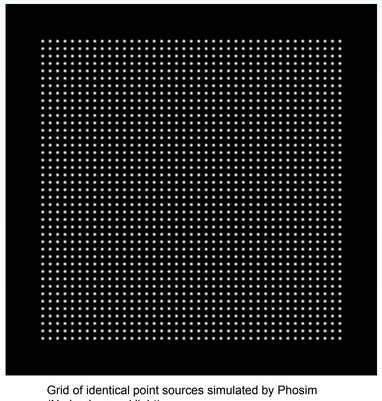
Objectives

In order to develop a procedure to calibrate tree ring biases:

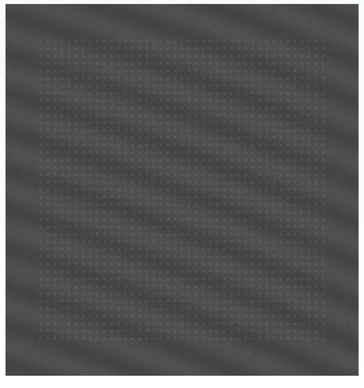
- Validate that Phosim's model of tree rings is comparable to measured data and expected relations.
- Use Phosim to explore the chromatic dependence of tree ring induced biases.

Methods

- Simulations done using Phosim in an ideal environment with assorted dopant concentration variation amplitudes.
- Used monochromatic fields of non-overlapping identical point sources and flat light sources for investigation.

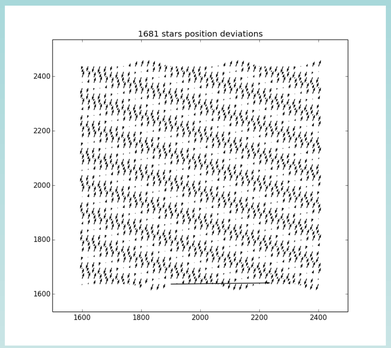


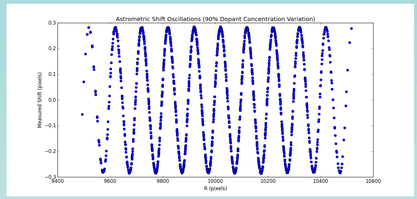
Grid of identical point sources simulated by Phosim
(No background light)



Simulation of grid of point sources with tree rings
visible in background light

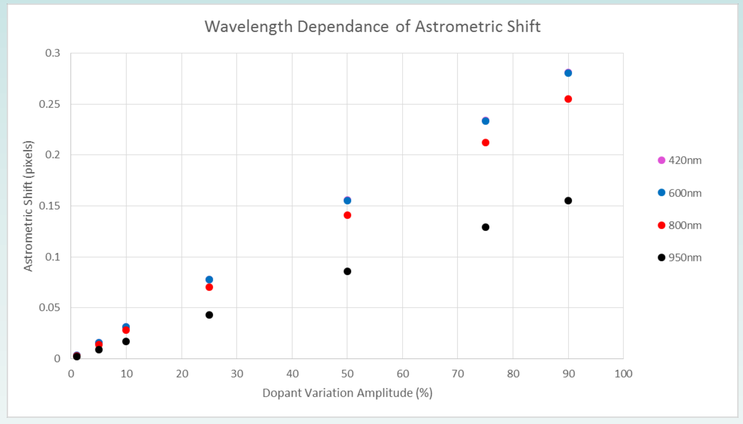
Results



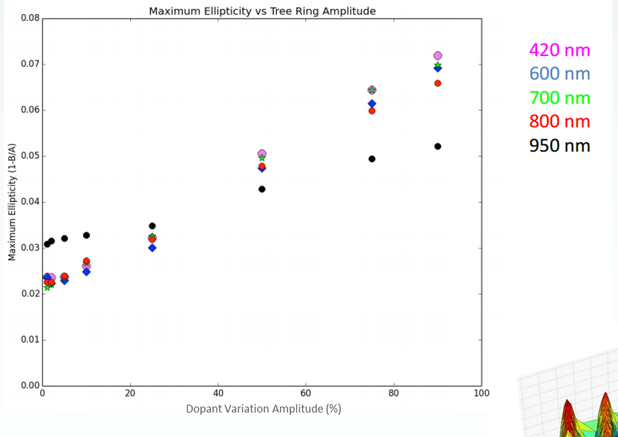


Above: Plot of the magnitude of the astrometric shift experienced by an object detected at a pixel a distance R from the tree ring origin.

Left: Vector plot of the magnitude and direction of tree-ring induced astrometric shifts for a grid of evenly spaced stars.

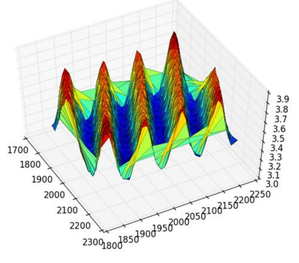


Above: Plot of magnitudes of induced astrometric shift for various wavelengths and dopant variation severities.



Above: Plot showing induced ellipticity as a function of the dopant concentration amplitude and the wavelength of the incident photons.

Right: 3D plot of object size as a function of the position it is detected on the CCD.



Astrometric Shift and Flat Field Intensity Variations

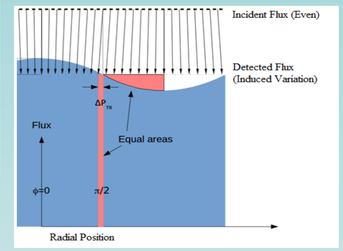
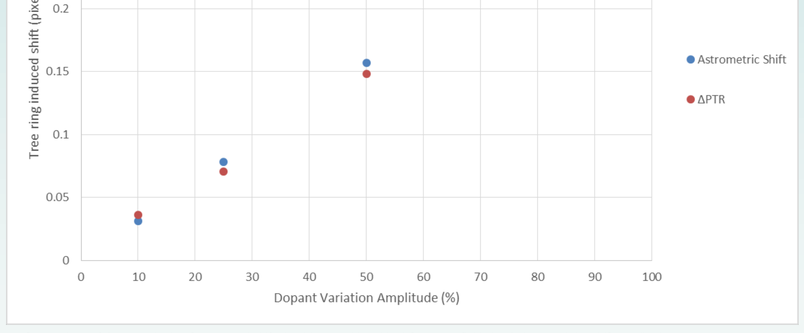


Figure courtesy A. Rasmussen

- Amplitude of flat field intensity oscillations and star field astrometric shifts linked by conservation of particle considerations
- Number of electrons forced out of the low-intensity regions should be equal to the average electron intensity times the maximum astrometric shift.
- Expected relation observed in Phosim simulations.

$$\Delta P_{TR} = \left(\frac{Period}{2\pi}\right) \times \left(\frac{\Delta Flux}{\langle Flux \rangle}\right)$$



Comparison of the magnitude of measured shifts in object position (blue) from star field simulations and the shift amplitude necessary to produce the intensity variations measured in flat field simulations (red).

Conclusions

- Phosim's tree ring induced biases comparable to those observed in actual DES sensors.
- Anticipated chromatic dependence of tree ring induced biases observed; Longer wavelength photons are less impacted by tree ring induced distortions as anticipated.
- Validated various aspects of Phosim's tree ring modeling and will apply to WL studies.

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